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THE DISTRIBUTION OF TRACHEÆ IN THE NYMPH OF PLATHEMIS LYDIA.

G. G. SCOTT.

The Odonata are regarded as among the most highly organized of insects. In fossil dragon flies found in the Tertiary are indications of high specialization. Dragon flies are especially adapted to swift flight. For this purpose they are supplied with broad wings and powerful muscles to work them. There is consequently a great need for a plentiful supply of oxygen. This is supplied to every tissue in all parts of the body by the tracheal system. On this account a study of the tracheal system is of interest and importance.

The late Professor James I. Peck, of Williams College, suggested to the writer in 1898 that he make a study of the distribution of tracheæ in the nymph of a dragon fly found near Williamstown, Mass. It is from notes and drawings made at that time that the present paper is written. The forms found were identified by Professor James Needham as *Plathemis trimaculata*, which name I am informed has since been changed to *Plathemis lydia*. Lubbock says that the larval tracheæ of insects are more generalized and represent more nearly the original type than those of the adult. The results of this investigation show clearly that on the other hand we have in the nymph of *Plathemis lydia* a very special and complex distribution of tracheæ in some respects especially adapted to aquatic larval life and changing to simpler conditions in the adult. Lubbock states that the distribution of the tracheæ depends on the size and shape of organs. Yet in the nymph of *Plathemis lydia* there are certain complexities that are not thus easily explained. For example the tracheæ

of one side cross over and fuse with the tracheæ of the opposite

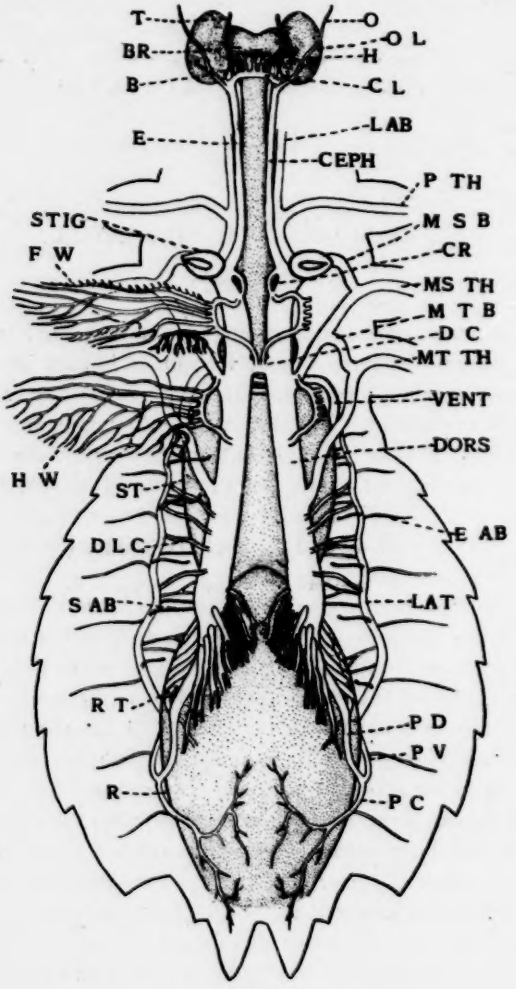


FIG. 1.

side. The distribution in the main however follows the contour of organs or axis in parts.

Plathemis lydia belongs to the family Libellulidæ of the order

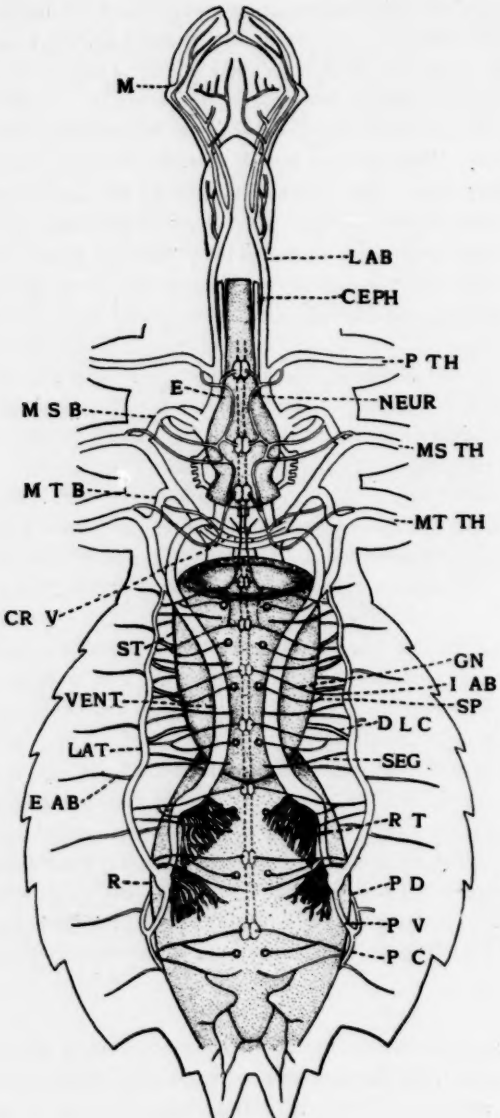
Odonata. The Libellulidæ are among the most highly organized of the Odonata. As far as the tracheal system is concerned *Plathemis lydia* is well classified. The nymph is aquatic, inhabiting the muddy bottoms of quiet pools. It has a swift darting motion when disturbed, caused by expelling water from the rectum. The average length of those studied was 23 mm., the width 7 mm. The head is marked by the large eyes at the upper outer angles ; a single pair of short antennæ extend from below and between the eyes. The prominent mask, a modified labium, covers the mouth parts. There are three pairs of legs, all attached to the thorax, which also bears dorsally two pairs of short functionless wings. Anterior to these is a single pair of prothoracic stigmata, functionless also. On the abdominal segments are found seven pairs of functionless stigmata. Internally the alimentary canal extends from mouth to anus and consists of esophagus (Fig. 1, *E*), stomach (Fig. 1, *ST*), intestine and rectum (Fig. 1, *R*). At the junction of the stomach with the intestine are the malpighian tubules. On the dorsal face of the gut over the rectum and stomach is the slightly lobed blood vessel. On either side of this and somewhat posteriorly are the immature reproductive organs.

Ventral to the gut is the chain of seven abdominal ganglia (Fig. 2) the posterior being the largest. The ganglia are connected by nerve cords to each other and by the same method anteriorly with the thoracic ganglia (Fig. 2). There are three of these not fused, the meta- and mesothoracic being nearer together than the meso- and prothoracic. The prothoracic ganglion connects by nerve cords with the subesophageal ganglion and this by the esophageal ring with the dorsally lying brain (Fig. 1, *br*). On the upper outer sides of the brain are the large optic lobes.

It is the tracheal distribution to the foregoing parts that I have worked out and also the connections and interconnections of the tracheæ.

Methods.

The nymph was placed in a strong solution of glycerine in a watch glass and the dissections made with small scissors and needles sharpened down to cutting edges. Most of the work was done with a dissecting microscope. In the glycerine solu-


M
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CEPH
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LAT
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R T
R
P D
P V
P C

FIG. 2.

tion the tracheæ appeared as silvery white tubes. Some of the more minute points were worked out teasing with needles under the lower powers of the compound microscope. Glycerine mounts were easily made and studied.

Tracheal Distribution.

According to Packard '98 the tracheal system of *Plathemis lydia* belongs to the peripneustic type in which the prothoracic and abdominal stigmata are present though not functional during the greater part of the larval life. This type is intermediate between the holopneustic or open type and the apneustic or closed type.

The Dorsals. — The tracheal system is most conveniently understood by considering first those that lie dorsally, then those that are ventral and those that run laterally. In connection with each of these three systems there will be given an account of their principal branches. The connections of each of the others will be described. The stigmata found dorsally between the pro- and mesothorax will serve as a convenient starting point. From each of the stigmata (Fig. 1, *STIG*) the two largest tracheal tubes, the dorsal tracheæ (Fig. 1, *DORS*) extend posteriorly, diverging slightly to the sides of the rectum. There is a small crescent-shaped trachea (Fig. 1, *CR*) arising from the inner face of the dorsals at the stigmata and joining the dorsals again a short distance behind.

About one fifth of their distance back of the stigmata the dorsals are connected by a trachea of about one half their own diameter (Fig. 1, *D C*). The trachea to the mesothoracic leg (Fig. 1, *MS TH*) arises from the dorsal just back of the above mentioned connective. It receives a branch (Fig. 1, *M S B*) from the dorsal at the stigmata. The tracheæ to the metathoracic leg (Fig. 1, *MT TH*) arises from the dorsal trachea posterior to the origin of the mesothoracic. The metathoracic also receives a branch (Fig. 1, *M T B*) from the mesothoracic trachea. The function of these short branches is not clear. They may serve as stays to hold the meso- and metathoracic tracheæ in place. Small tubes pass from the thoracics to the vertical wing muscles.

To the Wings. — Just posterior to the hinder origin of the crescent arises the anterior limb of a loop (Fig. 1, *F W*) which furnishes the fore wing with tracheæ. The posterior limb of the loop passes back and joins the dorsal connective. The posterior limbs of both the fore wing loops join the dorsal connective side by side (Fig. 1). Five tracheæ pass out from the face of the wing loop. By the successive branching of these five tracheæ the whole wing is supplied. The first or the most anterior does not bifurcate simply but sends about twenty short branches to the edge of the wing. The second and third branches are the largest and supply the greater portion of the wing while the fourth and fifth send fine branches to the posterior margins of the wing. The distribution to the hind wings is similar to that of the fore wings. There are five main tracheæ originating also from a loop whose anterior limb (Fig. 1, *H W*) arises from the mesothoracic a short distance from its origin from the dorsal. The posterior limb of the loop joins the dorsal midway between the origin of the meso- and the metathoracic tracheæ. In the larva the legs are used much more than in the adult. The wings on the other hand are functionless in the larva. Therefore it is not surprising that the tracheæ to the legs are much larger in the larva. And yet although the wings are not used there is a complex distribution to every part.

Anterior to the Stigmata. — Two pairs of tracheæ originate from the dorsal at the stigmata, an inner or cephalic pair (Fig. 1, *CEPH*) and an outer or labial pair (Fig. 1, *LAB*).

The labials (Fig. 2, *LAB*) pass alongside the cephalics for a distance, then down around the esophagus and out to the mask (Fig. 2, *M*), sending out many branches. The distribution to the mask should be noted, as this organ is in constant activity in larval life for the capture of prey. The prothoracic trachea (Fig. 1, *P TH*) arises from the labial, a short distance anterior to the stigmata.

The cephalics (Fig. 1, *CEPH*) pass along the dorsal face of the esophagus and can be traced forward to the brain. There they are connected by a loop (Fig. 1, *C L*) and from this loop five branches pass forward. The middle branch (Fig. 1, *H*) passes dorsally to the top of the head. The two pairs on each side (Fig.

1, *B*) pass forward into the brain, indicating that a considerable amount of oxygen is used in the metabolism of this organ. At the place where the loop joins the cephalic tube two branches arise together — one the optic (Fig. 1, *O*) passing out to the optic lobes (Fig. 1, *O L*) and the eyes. The other to the trophic (Fig. 1, *T*) passes down underneath the optic lobes and on out to the head parts.

Posterior Dorsals.— The dorsals give rise to branches supplying the alimentary tract — the blood vessel and reproductive organs and other adjacent tissues.

Posteriorly the dorsals become much smaller in size, this being due to the fact that each gives off many smaller tracheæ to the dorsal and lateral surfaces of the rectum (Fig. 1, *RT*). Most of these after much subdivision into fine tracheoles pass through the wall of the rectum to the rectal gills. One of the larger branches of the dorsal continues back as the post-dorsal (Fig. 1, *P D*), then passes down over the side of the rectum joining the post-ventral (Fig. 1, *P V*), which curves forward and inward on the ventral surface of the rectum connecting with the main ventral tracheal tubes (Fig. 2, *VENT*). At the place where the post-dorsal meets the post-ventral the former continues posteriorly up over the dorsal surface of the rectum (Fig. 1, *P C*).

The Ventrals. — Arising from the post-ventral the ventral tracheæ (Fig. 2, *VENT*) pass forward on the ventral surface of the rectum toward the mid line and diverge as they continue on the under surface of the stomach. At the anterior end of the stomach each ventral curves up and around crossing over the upper surface of the stomach. The right ventral finally joins the left mesothoracic trachea just beyond the latter's origin from the dorsal. Also the left ventral joins the right mesothoracic in a similar manner (Fig. *CR V*). Fig. 2 is drawn with the anterior part of the stomach removed to show the union of the ventral with the mesothoracics. It will be noted that the ventrals arising from the dorsals posteriorly join them again anteriorly. From the posterior ends of the ventrals tracheæ run to the ventral surface of the rectum and through to the rectal gills. In front where the ventrals are near together they send branches to

the malpighian tubules and furnish the greater tracheal supply to the stomach.

Lateral System. — At the posterior origin of the ventrals there arises also the lateral tracheæ (Figs. 1 and 2, *LAT*). These run anteriorly lateral to the alimentary tract and near the outer lateral edges of the abdominal walls. The laterals run forward decreasing in size and join the metathoracics just beyond their origin from the dorsals. From the lateral trachea a branch runs out externally (Figs. 1 and 2, *E AB*) to each of the first six abdominal segments supplying the muscles which assist in the compression of the abdomen. Adjacent to these tracheæ others arise from the upper face of the lateral and run to the dorsal part of each segment (Fig. 1, *S AB*). Then a third set of tracheals originate from the laterals along with the others. These the segmentals (Fig. 2, *seg*) pass ventrally along the hinder margin of each segment sending branches forwards the width of the segment. Finally a fourth set of tracheal tubes arise from the laterals in each segment, the inferior abdominal (Fig. 2, *I AB*) so named because they pass below the alimentary tract. They bifurcate a short distance from their origin from the laterals. The anterior branch (Fig. 2, *GN*) supplies the near half of the abdominal ganglion of that segment. The posterior branch (Fig. 2, *SP*) runs out to the abdominal spiracle of that segment. In the nymph as before described these spiracles are closed yet the tracheal distribution to them is clear.

The first of the ganglionic tracheoles sends a branch forwards to the metathoracic ganglion and a branch back to the second ganglionic trachea. The seventh abdominal ganglion and spiracle has a different supply receiving a branch from the posterior continuation of the dorsal (Fig. 2, *P C*). Near this arises another trachea which with a similar one from the other side forms a network in the posterior and ventral part of the body cavity. Only the main features of it are shown in Fig. 2.

The distribution to the thoracic ganglia is more complex. Each of the thoracic ganglia receives on either side a branch from the neural trachea (Fig. 2, *NEUR*). This trachea takes a somewhat tortuous course the length of the thorax alongside the thoracic ganglia. It receives a branch from the prothoracic

trachea—then just back of the mesothoracic ganglion it receives two branches, one from the mesothoracic branch (Fig. 2, *M S B*) and the other from the mesothoracic trachea itself (Fig. 2, *MS TH*). Finally the neural trachea receives two branches posteriorly. The first arises from the metathoracic branch (Fig. 2, *M T B*) the second from the metathoracic trachea (Fig. 2, *MT TH*). In addition the metathoracic ganglion as previously described receives fine tubes from the tracheæ which supply the first abdominal ganglion.

From the dorsal trachea posterior to the metathoracic there arise four tubes connecting the dorsal with the lateral trachea (Fig. 1, *D L C*). The lateral tracheæ at the anterior end are not much larger than these dorsolateral connectives.

Rectal branchiæ. — Like many of the larval dragon flies *Plathemis lydia* takes in air from the water which passes in and out of the rectum. The rectum of the nymph is proportionately much larger than in the adult. It is supplied with a complicated apparatus for separating the air from the water. The posterior end of the abdomen at the anus is provided with anal spines. There are three larger spines and a pair of smaller ones. Of the larger ones, two are ventral, one is dorsal while there is a single smaller spine between the dorsal and each of the ventrals. Just internal to these spines are three valves each adjacent to one of the larger rectal spines. The dorsal valve (Fig. 3, *D R V*) is the largest, the two ventral valves (Fig. 3, *V R V*) are of equal size. Each edge of the dorsal valve is met by the external edges of the other two, a triradiate slit being thus formed when the valves are closed.

FIG. 3.

The ventral valves seem to work on the dorsal valve as a base. When the valves close water is retained in the rectum. It is forced out again by the compression of the abdomen. If it is ejected with sufficient force the animal is propelled forward in the water.

This compression of the abdomen is brought about by means of muscles connecting the roof and floor of the abdomen at its external edges. Expansion of the abdomen is due to two causes, first the relaxation of the above mentioned abdominal muscles

and second the tendency of the walls to resume their somewhat cylindrical form. Extending the length of the surface of the rectum are six longitudinal bands or muscles (Fig. 4, *RM*) a dorsal pair, a lateral pair and a ventral pair. These muscles are equally distant from each other. To each of them internally is attached two rows of leaflike structures, the rectal gills (Fig. 4, *R G*) which extend into the cavity of the rectum. The dorsal trachea (Fig. 4, *D*) sends branches to the dorsal and lateral rectal gills. From the ventral trachea (Fig. 4, *V*) branches pass to

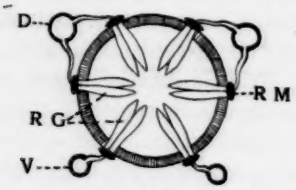

FIG. 4.

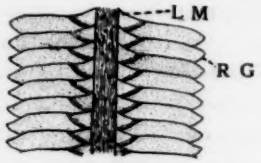

FIG. 5.

the ventral rectal gills. Fig. 5 shows the relation of the gills (Fig. 5, *R G*) to the longitudinal muscles (Fig. 5, *L M*). In this figure the gills are pressed out laterally. The shortest edge of each gill is attached diagonally to the muscle so that the lines of attachment of the two rows of gills of the same muscle have the appearance of a succession of "V's," the diverging ends being toward the posterior. Each gill is somewhat triangular in shape (Fig. 6, *R G*) the proximal edge attached to the longitudinal rectal muscles being much shorter. At one corner of this shorter side is a somewhat triangular space (Fig. 6, *TR SP*) differentiated from the rest in general appearance. Sadones '95 describes it in the gills of other species and gives no decisive clue as to the function of it. He ascribes, however, an excretory function to it.

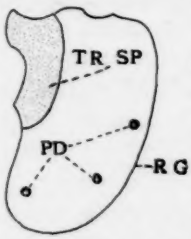

FIG. 6.

On one surface of the gill are three small pads (Fig. 6, *PD*) by which it is separated from the adjacent gills. The pads allow a thin film of water to form between each gill. Each gill is about

a millimeter in length. Oustelet, '69, estimates that there are twenty-four thousand respiratory folds in the larva of *Æschna cyanea*. These folds are not flat enough to be called gills; they are more like papillæ, but they serve the same function as gills. There are certainly as many in the rectum of *Plathemis lydia*. By the great number of folds or gills the surface area of the rectal breathing apparatus exposed to the water is increased roughly speaking about eight or ten times. As previously indicated the dorsal trachea after many subdivisions divides into two sets of tracheæ (Figs. 1 and 2, *R T*), a dorsal set and a lateral set (Fig. 4, *D*), supplying the dorsal and lateral rectal gills. The fine subdivisions of the ventrals pass to the ventral rectal gills. The final disposition of the finer tracheoles to the gill itself is shown in Fig. 7. In this figure four gills are shown teased apart. Each tracheole (Fig. 7, *G T*) bifurcates just before it reaches the upper edges of two adjacent gills of the same side. One branch (Fig. 7, *P*) passes to the posterior edge of one of the gills, while the other branch (Fig. 7, *A*) passes to the anterior edge of the gill behind. Each of these branches sends finer tracheoles into the gill. These divide and fill the gill in its most expanded portion with a network of tracheæ.

Examination under high power shows that the tracheoles (Fig. 8, *T*) from the posterior and anterior gill tracheæ form loops overlying one another (Fig. 8, *AA*). The condition in

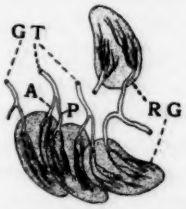

FIG. 7.

FIG. 8.

Plathemis lydia then confirms the work of Sadones, '95, who found in the Odonata he studied that the gill tracheoles were found in loops and therefore connected. A close examination of his figures, however, shows that he has drawn the tracheæ ending blindly and not in loops.

Oustelet and Palmén state that this rectal breathing apparatus does not disappear at the last ecdysis of the nymph but remains, though functionless. Hagen says that in a form he studied the whole structure disappears at that time. Whatever be the case, as far as the final moult is concerned, it is true that in the adult *Plathemis lydia* the rectal breathing apparatus has disappeared. There is indeed no further use for it since the stigmata are then functional.

The tracheal system in the nymph of *Plathemis lydia* differs in most of its details from that of *Æschna cyanea* described by Oustelet, '69. He describes four main trunks extending the length of the body and a pair of smaller abdominal tubes. These correspond to the dorsals, ventrals and laterals in *Plathemis lydia*. The four main trunks supply the rectum and respiratory papillæ in a manner roughly similar to that in *Plathemis lydia*. In *Æschna cyanea*, however, the rectal tracheæ arise from the hinder part of the dorsal at regular intervals, while in *Plathemis lydia* the hind part of the dorsal abruptly breaks up into many fine branches. The rectum of the former is furnished with respiratory papillæ, while the latter has flattened leaf-like gills. In both the tracheoles are present in loops.

In agrionid nymphs there are three long, flat caudal processes thickly supplied with tracheæ, and serve as an apparatus for taking the air from the water into the tracheal system. They are morphologically identical with the caudal spines in *P. lydia*. In the nymph of *Calopteryx*, an agrionid, there are a few internal rectal gills in addition to the three long caudal gill processes. In these forms the gill apparatus is mostly exterior. In the Æschnidæ the branchial apparatus is within the rectum. The inside surface of the rectum is provided with six longitudinal bands, each bearing a double row of folds or papillæ. In the Libellulidæ, of which *Plathemis lydia* is a member, we find not papillæ but flat processes or gills.

In the Libellulidæ there is found the highest form of the rectal gill breathing apparatus, the most specialized branchial arrangement of these three groups. On the other hand the Agrionidæ have the simplest form while the Æschnidæ have the form of branchiæ intermediate between the other two. If we were to

arrange these families according to branchial complexity we would have the following order: (1) Agrionidæ, (2) Æschnidæ, (3) Libellulidæ. And this is the order in which they are arranged by systematists. It merely indicates that the tracheal system is correlated in its complexity with the complexity of other parts, and corroborates Lubbock's statement that the tracheal system conforms to the contour of parts.

As to the phylogenetic origin of the branchial apparatus very little is known. Chun, '75, stated that Leydig had described in *Phryganea grandis* a structure which indicates that the rectal branchiæ of Libellulidæ might be considered as being developed from the rectal glands of other insects. Sharp, '95, after careful examination of Leydig's work failed to find such reference. Chun and others, however, have regarded this as the probable origin of branchiæ. Sadones, '95, after a careful examination of the evidence concludes by saying that Chun and the others who hold the above views persist in "perpetuant une notion erronée des anciens anatomistes."

In the nymph of *Plathemis lydia* the pair of thoracic stigmata between the pro and mesothorax are practically closed. When the nymph is placed in a thick solution of glycerine it invariably comes to the surface and protrudes the posterior end of the abdomen out of the fluid, the anal valves opening and closing vigorously. The caudal end always protrudes, indicating that the stigmata are not functional as yet. Hagen, '80, on the other hand believes that the thoracic stigmata are functional in the nymph. The best evidence is furnished by Dewitz, '90, who conducted a series of experiments. When the older nymphs of *Æschna* were placed in alcohol bubbles escaped from the thoracic stigmata. But in immature nymphs no gases escaped though these were subjected to a much severer test. The transition then from rectal gill breathing of the nymph to the open stigmatal type of the adult is not as sudden as ordinarily supposed, but that as the nymph grows older it gradually changes from gill breathing to the open stigmata of the adult.

When one recalls that the fine tracheoles to the rectal gills originated ultimately from the dorsal and ventral tracheæ and that these are connected posteriorly and anteriorly then it ap-

pears clear that it is hardly correct to assign the carrying of pure air to one set of tracheoles in the gill and the carrying of impure gas to the other set of tracheoles. A detailed examination of the tracheal system demonstrates not only its complexity but its many interconnections and therefore its unity. It may be regarded as the lungs of the animal whose branches ramify throughout the body, present in every tissue, carrying oxygen to every cell directly and returning the products of respiration from the tissues to the exterior. It is an arrangement admirably adapted to an organism leading a very active life — much more active than that of many of the higher forms.

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OBSERVATIONS ON THE PROGENY OF VIRGIN ANTS.

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The value of the experimental work here presented lies mainly in the complete protection of the virginity of the ant-mothers during their whole lifetime, or from their pupa-stage to the close of the experiments undertaken with them, and in the perfect safeguarding of their eggs from contact with spermatozoa outside the body of the ant.

At the present time, so far as is known to the writer, published observations on the offspring of worker ants may be placed in three categories. Those in the first category present a possibility that a queen's eggs were inadvertently included in the nest with the workers sequestered. When ants are transferred from a natural to an artificial nest, it often happens that eggs, unobserved at the time of sequestration, are discovered in the new nest within a few days thereafter. Ants are tenacious of their charges, and they sometimes conceal eggs or small larvæ in their mouths, or carry them adhering to their persons. In this way eggs may be unwittingly transferred to the new abode and may afterward be brought together in a pile or packet, the observer believing them to be the product of the worker-ants when they are really the issue of a queen in the old habitation. Unless the ants were singly and carefully examined and freed from adherent eggs, or unless a longer time than the twenty days ordinarily required for incubation has elapsed since the segregation of the workers, there is reason for suspecting that the eggs may have been deposited by other ants than the sequestered ones.

In a second category may be included all those cases in which larvæ were intentionally introduced among the segregated ants. Such larvæ may not have reached the pupa-stage sooner than the issue from eggs deposited in the new nest, and it is impossible to maintain that the older and the younger larvæ are always distinguishable. I have had, in my artificial nests, larvæ of *Cremastogaster lineolata*, scarcely larger than the eggs from

which they emerged, remaining for many months without visible growth, and then developing simultaneously with the issue of eggs deposited a half year later. I am informed by Dr. J. H. McGregor that larvæ of *Camponotus americanus* have remained such during ten months in his artificial nests at Columbia University; and by Dr. I. A. Field that larvæ of *Camponotus pennsylvanicus* remained under his observation in apparent good health and without visible growth for nearly fifteen months. Admitting that certain eggs were deposited by workers, we still lack assurance that introduced larvæ were not mingled with their issue, and thus there is created a reasonable doubt as to the origin of the callows appearing in the nest at a later date.

To a third category we may relegate the numerous accounts, including my own, concerning the offspring of workers that had previously lived with males, and also those accounts in which male ants were hatched and permitted to remain within the segregated group of workers. We know that ants sometimes mate within the nest, and we have the results of many dissections indicating the capacity of certain workers for impregnation. Miss Holliday [1] found not only ovaries but a seminal receptacle in certain individuals representing three genera of ponerine, two genera of myrmicine, and one species of camponotine workers, none of whom was externally distinguishable from its fellows. We can no longer consider the workers of all species of ants as sterile females. In view of the evidence that among workers, showing no difference in external structure there have been found, in numerous species, many members with both ovaries and seminal receptacles; and of the testimony of competent witnesses that the male ants sometimes pursue the workers with an ardor equal to that shown in their pursuit of the queens, we must abandon the long cherished notion that eggs deposited by worker ants are always unimpregnated.

We do not know even that ant-eggs may not be fecundated outside the body of the female, and this possibility should not be ignored in cases where the egg-piles are traversed by mature males in pursuit of queens and workers.

[1] "A Study of some Ergatogynic Ants," Margaret Holliday. Contribution from the Zoölogical Laboratory of the University of Texas, June, 1902.

The absence of indubitable proof that the unfecundated ant-egg produces either male or female ant impelled me to undertake the formation of ant-groups in which no member had ever lived with a male, and from whose abode males were excluded. In the summer of 1904 I sequestered pupæ, with two or three workers to take care of them, in artificial nests in which there were neither queens nor males, and as soon as these pupæ hatched I segregated the callows in new nests into which no egg, larva or pupa was ever introduced. My ant-groups were thus made up of workers indubitably virgin, and the eggs deposited in their nests were certainly unimpregnated.

Group A. *Camponotus pictus.*

Group A consisted of thirty workers, majors and minors, of *Camponotus herculeanus pictus*, hatched between July 11 and 31, 1904, and kept in segregation from their hatching until October, 1905. Their first eggs, ten in number, were deposited between May 14 and 18, 1905, and these had increased to about fifty on June 4. The first larva appeared on June 6, nineteen days after the first eggs were observed. On July 7 the larvæ had made notable progress in number and in size, the largest then being as long as an adult worker. The first cocoon was spun on July 16, and the first offspring of these segregated virgin workers appeared on August 14. Between August 14 and September 30 their cocoons gave forth thirty-two notably large and sturdy males. That no female might escape observation if hatched from these cocoons, the cocoons were transferred, soon after their formation, to an annex of the nest where only five workers were admitted. Cocoons and nurses were daily counted, and it is certain no queen nor worker ever hatched from these cocoons.

Group B. *Formica argentata.*

Group B consisted of about fifty *Formica argentata* workers, all hatched from sequestered cocoons during September, 1904, and kept in segregation by me from the time of hatching until after the close of this series of observations. From eggs deposited on July 7, 1905, the first larva appeared on July 19. The first cocoon was spun on August 4, and the first ant hatched

on August 31. Only five cocoons were formed in this nest, and each of these rendered a large, fine male.

DR. FIELD'S GROUP C. *Formica argentata.*

Dr. Irving A. Field, who simultaneously with myself, sequestered pupae from the same wild west that provided my B group, likewise segregated virgin workers, to the number of one hundred and twenty-five, all hatched between August 20 and September 23, 1904. From eggs laid between June 6 and 13, 1905, the first larva appeared on June 21; the first cocoon on July 23; and the first callow on August 7. All the young produced in this group were males, of which fourteen had appeared before September 3, 1905.

DR. FIELD'S GROUP D. *Formica pallide-fulva fuscata.*

This group, while failing to meet prescribed conditions in so far as the workers were not sequestered during the whole of their lives, is herein inserted because its history is clearly recorded. It consisted of many workers, secured by Dr. Field, at Middlesex Fells, Mass., on March 15, 1904. The ants were frozen in a mass when taken from the ground, and every ant was so carefully examined before her insertion into the artificial nest that there is no probability that eggs were introduced into the segregated group of workers. This group remained under Dr. Field's observation at Harvard University. It was placed in a chamber having a temperature of from 75° to 85° F. or from 23° to 30° C. On March 20, five days after the sequestration, the first egg was laid; on April 4, the first larva appeared; and on April 17, the first cocoon was spun. Before June 10, forty-six males had appeared in this nest; and no other than male young had been produced.

GROUP E. *Cremastogaster lineolata.*

The progeny of a queen ant whose life-experiences have all been under observation, is believed to be here for the first time enumerated.

On August 18, 1903, a queen *Cremastogaster lineolata* hatched in a sequestered group of pupæ in one of my artificial nests[1]

[1] My ants were under my care at the Marine Biological Laboratory at Woods Holl, Mass., during the summers, and at my home in New York City during the remainder of the year.

and was immediately removed to a small nest, where there were several newly hatched workers and males of *Stenamma fulvum*, this group being originally created for observation of the behavior of a queen having a family made up of ants of other species than her own. When the queen was but a few days old, I clipped off her wings to secure her greater safety from accident among the viscid food-stuffs in the nest. During the ensuing year, all the males died, and three more were hatched from eggs deposited by the *Stenamma* workers. I did not expect this queen to lay eggs, because I had previously kept unmated queens (of *Stenamma fulvum*) a whole year without their losing their wings or depositing an egg during that period. Dr. McGregor also kept winged queens (of *Camponotus americanus*) ten months without their losing their wings or depositing eggs.

On July 31, 1904, I removed all the *Stenammas* from this nest, cleaned it thoroughly, and gave to the queen forty newly hatched workers from her own colony, probably her own sisters. Three days later there were ten eggs in the nest, and on August 21 there were more than three hundred. That these eggs had been laid by the queen was indicated by their size and by the immaturity of all the workers in the nest. The queen was eight millimeters in length, the workers only three to four millimeters. Moreover, I compared the eggs with those of an isolated queen, *Cremastogaster lineolata*, and found them to match precisely.

Young larvæ were first observed among the eggs on August 28; the first pupa appeared on December 22, 1904, and two males hatched on January 10, 1905. These, when a day old, were transferred to Dr. W. M. Wheeler for expert examination concerning signs of hybridization, and were by him reported to be typical *Cremastogaster lineolata* males. Their successors in the nest were like them. No male was permitted to mature in the nest, all except the first two being removed before hatching. Before the end of September, 1905, sixty-three males had been produced in this nest, the offspring of this virgin queen. No young queen or worker had been seen, though the pupæ in this species are always naked, and the young had been carefully examined at least twice a week.

While this *Cremastogaster lineolata* virgin queen was producing

male offspring only, a queen, *Camponotus pennsylvanicus*, living in a similar nest of mine, supplied with the same food, subject to the same daily temperature, and having about the same number of worker-servants, produced numerous offspring, exclusively female. The *Camponotus* queen had been captured when deälated, presumably after her mating. Although these queens were of different subfamilies among the ants, the similarity in all the conditions of their environment except the incident of mating, points to a probability that the sex of their respective progeny was determined thereby, unimpregnated eggs producing males, and impregnated eggs producing females.

It is an interesting fact that during the twenty-six months that this *Camponotus pennsylvanicus* queen remained under my observation no male appeared among the many tens of her offspring; while eleven of her segregated daughters in the care of Dr. Field produced at least three male, and no female, offspring.

The observations here recorded establish the view that some virgin workers lay eggs, and that many ant-eggs that have had no contact with spermatozoa produce males. Not until female progeny shall have been observed to issue from eggs protected as were those of my *Camponotus pictus* should we consider the Dzierzon theory inapplicable to ants. No ant indisputably virgin, with her eggs perfectly safeguarded from spermatozoa, has yet presented evidence against the extension of this theory to the Formicidæ.

MARINE BIOLOGICAL LABORATORY,
WOOD'S HOLL, MASS., September 1905.

TEMPERATURE AS A FACTOR IN THE DEVELOPMENT OF ANTS.

With Further Observations on Ants Deprived of Food.

ADELE M. FIELDE.

Some recent experiments made by me lead to the conclusion that temperature is a dominant factor in the development of ants; that, other things being equal, it determines the time of the deposit of the eggs, the length of the larval period, and the hour of exit from the cocoon; and that the developing young of unlike species of ants are differently affected by the same degree of heat. It also appears probable that unlike species of ants develop and deposit their eggs at different temperatures, fixed for each species.

The greater activity of the adult ants in higher temperatures, with the increased movement of the anterior end of the larva which may be observed when the temperature rises, and the quickening of the pupæ which occurs in the hottest days, are doubtless an effect of the stimulation of metabolism by heat.

Experiment A.

My N. queen *Camponotus pennsylvanicus* laid eggs in the first week in August, 1903, which were kept in my living room where the temperature seldom rose above 70° F. or 21° C., and the earliest ant to issue from these eggs hatched on April 25, 1904, when the temperature had risen to 78° F. or 26° C. On July 14, 1904, I removed this queen to a new nest, where she was kept at a temperature that seldom rose above 70° F., and she laid no eggs until after I had, on November 20, 1904, removed her to a room where the usual temperature was from 82° to 85° F., rarely falling to 70° F. and occasionally rising to 90° F. On December 2 I observed twenty eggs, which had increased to sixty on December 11. The first larva appeared on December 18. On December 30 all the eggs had hatched and there were several tens of larvæ. The first cocoon was spun on January 8, and the

first callow appeared on January 29, 1905. This indicates about twenty days for incubation, a month for the larval and twenty days for the pupal period, all at a time when the congeners of this queen were merged in winter repose.

This N. queen shared the labors of the workers in the care of the young, which continued to develop until the 26th of March, when I removed the nest to a room having a fairly steady temperature of 70° F. At this temperature the remaining cocoons failed to hatch, and the fifty larvæ ceased to grow. The larvæ did not increase in size till the last days of the following June, after the temperature had risen to 76° F. The first cocoon of this newer brood was spun August 6, 1905.

Although this queen had deposited eggs in March, 1904, she deposited none in March, 1905, nor did she lay any thereafter until July 26, 1905, when she again deposited a few eggs. During the first week in August, 1905, the eggs were increased to about the same number that she had laid at the same season two years previously. Her failure to lay eggs in August, 1904, was doubtless due to the agitation consequent upon her service in several of my experiments at about that time. I have often observed that psychic influences affect the deposit of eggs by ant queens. Her failure to lay eggs in March, 1905, was probably due to exhaustion consequent upon the work to which she had been stimulated by high temperature in the previous December.

Since the food supply, the humidity, and the number of workers were factors whose variation was but slight in the nest of this queen, it appears probable that the time of the development of eggs and the growth of the young was determined mainly by the temperature.

Experiment B.

My *Cremastogaster lineolata* queen laid hundreds of eggs in August, 1904, and the larvæ therefrom grew scarcely at all until, on November 20, 1904, I removed her nest from a room where the usual temperature had been 70° F. to a chamber where the temperature was usually from 82° to 85° F. Early in December the larvæ began to increase in size and on December 22 the first pupa appeared among them. The young continued to thrive and fifty-three pupæ had been developed in the nest before March

26, 1905, when I removed the nest to a room having a usual temperature of 70° F. No more pupæ developed thereafter until late in the succeeding summer. The larvæ remained in a state of arrested development from the end of January until the end of the following June, when, under the influence of the natural rise in summer heat, they entered upon a period of renewed growth and in August presented me with ten more pupæ.

This queen laid eggs in June, when the temperature rose to 75° F., and continued to deposit them at various times throughout the summer.

Experiment C.

A group of thirty workers, majors and minors, of *Camponotus herculeanus pictus* hatched between July 11 and 31, 1904, were kept at the temperature of 70° F. or 22° C. until November 20, when they were removed to a chamber whose usual temperature was from 82° to 85° F. or 28° to 30° C. On March 26, 1905, they were returned to their place in my living-room, where the temperature was usually at 70° F. They laid no eggs until May 14, and then deposited about fifty before June 4, 1905, apparently under the influence of a rise in the temperature to 78° F. or 25° C.

The age of these ants may, however, have had influence on the time of egg-laying. It would be interesting to ascertain, by dissections of worker-ants, whether differences in the degree of development of the ovaries in workers of the same species is correlated with difference of age in the respective workers. It may be that the ovaries of many worker-ants do not develop until some months, or until the second season, after hatching.

Experiment D.

A group of fifty workers, *Formica argentata* hatched during September, 1904, were kept by me at a fairly steady temperature of 70° F., and laid no eggs until after they were removed to a chamber having a usual temperature of from 82° to 85° F. Their first egg was deposited on January 1, 1905, and during the ensuing week the eggs increased rapidly in number, so that on January 8 there were more than one hundred. The first larva was observed on January 15. None of the larvæ reached the

pupa-stage, and all these eggs and their issue had disappeared before March 19. On March 26 this nest was removed to a room having a temperature of 70° F., and these ants ceased from egg-laying until the temperature again rose to more than 80° F. in the following July. The young larvæ from the July eggs rapidly disappeared in the intense heat of July, 1905, and only five of them spun cocoons. It seems that the development of the eggs of this species demands a high temperature, while the development of the larvæ requires a lower degree of heat.

Dr. Irving A. Field, keeping a nest of one hundred and fifty worker-ants of this species, at Harvard University, gives me the following account of said nest: "The ants all hatched between August 20 and September 23, 1904. They laid no eggs until after November 30, when the nest was placed in a chamber having a temperature of from 75° to 85° F. Between December 30, 1904, and January 9, 1905, about a hundred and fifty eggs were laid, all of which were subsequently addled or else were eaten by the ants. But between June 6 and 13, 1905, about sixty eggs were laid, and from these, in natural summer temperature, many larvæ safely passed to the pupa-stage."

Experiment E.

I had one group of virgin workers of *Stenamma fulvum* two years old; one group of virgin workers of *Stenamma fulvum* one year old; and one group of virgin workers of *Camponotus americanus* newly hatched, that deposited no eggs during September, October and November, 1904, when they were kept at a temperature of about 70° F. But in all three of these groups, eggs that produced larvæ were deposited between November 20, 1904, and March 26, 1905, when they were kept at a temperature of from 82° to 85° F.; and all were again subjected to a completely arrested development of the young when the temperature fell to 70° F. between the end of March and the middle of June, 1905.

Groups of virgin workers of *Formica Schaufussi* and of *Formica neogagates*, housed, fed, and kept at the same daily temperature as were the above named ants, laid no eggs during either the

periods of low or of high temperature, but deposited eggs after the middle of June, 1905, when the summer heat rose to 78° F.

Other Experiments.

Dr. Field had a nest of workers of *Formica pallide-fulva fuscata* in which many eggs were deposited in March, 1905, when kept at a temperature of from 75° to 85° F. and the issue of these eggs passed safely through the larval and pupal stages at the same temperature. Dr. Field had also a nest of *Camponotus pennsylvanicus* workers who failed to rear their larvæ to pupation in the summer of 1904, but who, under the influence of the above named high temperature brought three to pupation in January, 1905.

Dr. W. M. Wheeler writes to me that *Formica consocians* workers in his artifical nests deposited many hundreds of eggs, in March, 1905, in a room whose temperature never rose above 60° F. or 15° C.

It appears that the time of development may be altered by change of the prevailing temperature and that an intervening period of recuperation will be maintained in spite of a continued temperature-stimulus. Other factors being equal, the development of the eggs within the ovaries, the deposit of the eggs, the feeding and growth of the larvæ, the pupation and the hatching, all appear to be determined by temperature. The degree of heat suiting the species probably varies for the different stages of development.

All the ants involved in my experiments had the same food-supply, the same daily temperature, and similar housing. They were abundantly provided with insect-food and with a variety of sweets. They always appeared to be in excellent health, and hardly any deaths occurred in any of the nests mentioned. It is therefore difficult to refer behavior so varied to other cause than the varying effects of the same temperature on unlike species of ants, or to avoid the inference that in different species the young develop best at different degrees of heat.

Among the ant-young observed by me, none has developed at a temperature below 70° F.; while long exposure to a degree of heat above 90° F. manifestly causes injury. Two minutes ex-

posure to a temperature of 122° F. or 50° C. will kill the most vigorous adult.

Further Observations on Ants Deprived of Food.

Among the groups mentioned in my paper on "Tenacity of Life in Ants" (in the Biological Bulletin, Vol. VII., No. 6, Nov., 1904, p. 300) were seven *Formica subsericea* workers that had been deprived of food three months and remained alive at the time of writing. These seven ants had been picked up from a roadside where they were foraging under a linden tree, on July 3, 1904. They were kept in a Petri cell containing only themselves and a bit of sponge saturated with water. Cell and sponge were cleansed with alcohol at intervals never exceeding four days, until the end of September, after which time the cell and sponge were cleansed only once a week. No growths were at any time visible under a lens magnifying ten diameters.

On February 3, 1905, one of these ants was removed for dissection, after an enforced fast of just seven months. One died on November 27, one on November 29, 1904; one on February 17, one on February 19, one on March 14, and one on March 28, 1905, the latest survivor having lived nearly nine months without food.

A *Camponotus Americanus* worker, under like conditions, lived without food from July 13, 1904, to February 12, 1905, just seven months.

Two sister queens, *Camponotus Americanus*, one dealated, one winged, under the same conditions, lived without food from July 13 to December 6, 1904, both dying on the same day. These queens had been bred in an artificial nest, and may have lacked the stamina of untamed ants.

After the first of October, all these fasting ants were kept at a fairly steady temperature of 70° F. or 21° C.

Until the day of death the ants walked about, reacted normally to light and heat, and gave no evidence of failure in any of the senses.

In spite of the prolonged fast, there was no fighting nor cannibalism in any group of these ants, and the bodies of those that had died were always found to be intact.

The ability of ants to survive a submergence of several days in water explains their persistence in areas where freshets periodically exterminate all other land insects, and their power to live for many months without food explains their occupancy of places subject to long droughts that destroy their whole food-supply.

MARINE BIOLOGICAL LABORATORY,
WOOD'S HOLL, MASS., September, 1905.

NOTES ON THE VARIATIONS OF RHEGMATODES.

CHAS. W. HARGITT.[1]

During the summer of 1900 I collected about two hundred specimens of *Rhegmatodes tenuis* for the purpose of studying its development. But this I was unable to carry out, owing to the inability of keeping the medusæ long enough in the aquarium to secure the eggs, few seeming to bear ripe gonads at the time of capture.

It was observed that many specimens showed more or less variability, and attention was then directed toward a study of the variations exhibited among the various organs. The comparatively few specimens obtained led to the postponement of a final study of the problem, hoping to secure additional material. This has been carefully sought during three subsequent summers, but in vain; only during 1902 have any specimens at all been found, and these very few and immature. The following "Notes" are therefore submitted as a slight contribution to the general problem of variation among Hydromedusæ, a more extended account of which was made by the writer in 1901.[2]

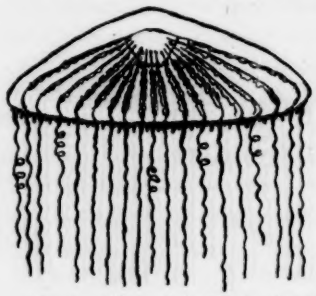

FIG. 1. *Rhegmatodes tenuis.* Semi-diagrammatic.

The general features of *Rhegmatodes* are shown in Fig. 1. The medusa varies in size at maturity from about 50 to 95 mm. in diameter. In younger stages the shape is more or less hemispherical, the tentacles and radial canals very much fewer in number, the earliest stage which I have found having but four canals and four tentacles. With growth the number increases very largely, but they are not correlated as at first, the latter becoming more numerous, besides also varying numbers of ten-

[1] Contributions from the Zoölogical Laboratory, Syracuse University.

[2] BIOL. BULL., Vol. II.

tacular spurs or clubs between the bases of the fully developed ones.

In view of the constantly increasing number of these organs, which are the more prominent organs usually involved in variation, it might seem a very uncertain problem to undertake anything like a critical determination of the quantitive variations. So far as the merely numerical aspects of variation are concerned this is undoubtedly true, as will be seen. I may, therefore, say in the outset that, both in view of the doubt just expressed, as well as in the comparatively small number of specimens available, no attempt will be made to present anything like a statistical account. It will be the purpose, rather, to submit a brief account of variations of a qualititative, or substantive character.

So far as I am aware, the only account of variations in the Family Æquoridæ is that submitted by Claus,[1] concerning *Æquorea forskalii* in a sharp critique of Haeckel's multiplication of species, and enlargement of the scope of the family. Claus calls attention to the striking differences exhibited by young specimens as compared with adults, and also to the almost equally marked differences as to coloration found in specimens of various ages and sexes, as well as to the highly variable character of the number of canals, shape of mouth and oral arms under different conditions of contraction, etc.

In connection with his description of *Rhegmatodes floridana*, Dr. A. Agassiz has merely referred to the fact that in the Æquoridæ, "the chymiferous tubes especially are very irregularly formed. They are frequently added all on one side of the spherosome, and almost fully formed before they begin to develop in the other half."[2]

The matters involved in these observations, while both of importance, hardly touch the more fundamental problems of variation as now understood. The critique of Claus is eminently fitting as a protest against the unwarranted multiplicity of species based upon such flimsy characters as those cited. The matters referred to by Agassiz deal more directly with phases of development than with those of variation, though closely related thereto,

[1] Arbeit. Zoolog. Inst., Wien, 1881, p. 283.

[2] "North. Am. Acalephæ," 1865, p. 97.

as will be seen in some of the illustrations of features to be described presently.

In view of the difficulty in accurately studying the otoliths of preserved specimens no attention has been paid to that feature, except incidentally. Something of a similar sort is true concerning the matter of variation in tentacles. They are so subject to mutilation and loss, to inequalities of regeneration, etc., that these also have not been given special attention in connection with this species. Chief attention has been directed to the radial canals, and to a less extent the gonads.

Asymmetry.

In a few cases marked asymmetry was apparent. In Fig. 2 is shown a condition found in several specimens. In the particular one from which this sketch was made the medusa had 24 radial canals, 12 of which were within a single quadrant of the umbrella, the others being about equally distributed over the other three fourths of the body. As will be observed, several of these canals were incomplete, as were also the associated gonads, the latter appearing to be either rudimentary or tending to degenerate. A somewhat similar condition is shown in Fig. 8; where in addition to the asymmetry, and incompleteness of several of the canals, there is also a fusion of the terminal portions of some of the canals.

The earlier citation of the account of Agassiz concerning the very "irregularly formed" condition of certain of these canals during development is significant in this connection. It would seem as if the condition involved in the case from which this illustration was drawn might be of a similar nature, though in the present instance, it must be remembered, that we are dealing with an adult and not a young specimen. It may not be improbable that in certain instances these apparent irregularities found during development may persist as permanent conditions in the adult

Radial Canals.

Attention has been already directed to the fact that the canals increase in number with the growth and age of the medusa. No attention need be taken therefore of this feature in relation to

variation, though when it is remembered that in the vast majority of all Hydromedusæ the radial canals are normally but four in number, the question naturally arises as to the conditions under which this extraordinary increase has arisen, and what it may signify. Such an inquiry would, however, lead too far afield for our present purpose. Mayer has raised and briefly discussed

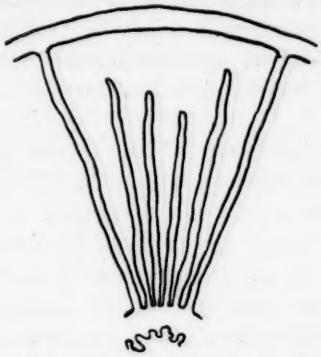

FIG. 2. Showing series of imperfect canals.

FIG. 3. Showing central and peripheral development of radial canal.

the problem in connection with a study of "The Variations of a Newly Arisen Species of Medusa."[1] In this paper Mayer suggests that one of the ways in which a pentamerous medusa may may have arisen from an ordinary tetramerous form is by bifurcation of one of the canals, which, if it became hereditary, would easily account for the condition of pentamerism.

The present writer has discussed somewhat the same general problem in an earlier paper (*op. cit.*, p. 239). If one had only a pentamerous or hexamerous condition for which to find some simple explanation, that just suggested might appear adequate. But when we have conditions like that of *Rhegmatodes*, not to mention many others of a similar sort, it will be more or less clear that such an account would be inadequate. It would seem far more probable that these supernumerary canals have arisen under the appropriate stimulus entirely independent of any special phyletic relations.

[1] "Variations in a Newly Arisen Medusa." *Bull. Brooklyn Inst. Arts and Sciences*, Vol. I.

In Figs. 3–5, as well as in those already cited, are shown interesting and more or less common forms of variant canals. Similar conditions are also to be distinguished in several of the other figures given. For convenience we may discuss these features under the following heads: (1) Bifurcations, (2) loops, (3) spurs, (4) anastomoses.

It may be altogether probable that these conditions graduate somewhat insensibly into each other, so that they may really be but varying expressions of one and the same fundamental process But as suggested, such a classification will at least serve as a convenience in description.

1. *Bifurcations.* — Several illustrations of this feature have already been cited. Others are shown in Figs. 4–6. For the most part these apparently arise as a result of division of the peripherally developing canal, though the centripetally directed type is not lacking, as is seen in Fig. 4. It may be said in passing. that the figures given are for the most part typical ones, each representing usually several similar cases. In development the

FIG. 4. Showing centripetal and centrifugal canals with bifurcations.

FIG. 5. Showing union of peripheral portions of two canals.

canals usually arise at the gastric pouch and grow toward the periphery. Agassiz (*op. cit.*) has said upon this point, "Additional chymiferous tubes in the Æquoridæ are developed from the digestive cavity, as shown by Kolliker, and not from the vertical tube, as in the case of the branching tubes of *Willia*." This I have found to be the case in a study of the very young medusa. On

the other hand, it must not be overlooked that in the Geryonidæ we have for the most part the opposite process, namely, the tubes arising from the marginal canal and developing centrally. Then in Figs. 4, 5 and 6, we have conditions which seem to show undoubtedly that such has been the mode of origin and development in *Rhegmatodes*. It brings before us, therefore, a form of variation at once morphological and physiological, or perhaps better, embryological.

2. *Loops.* — In Figs. 7 and 8 are shown what has seemed best described as loops. These seem to have resulted from the fusion of two or more canals whose terminal portions have approximated each other and finally become confluent. These were more or less common conditions among these medusæ. In

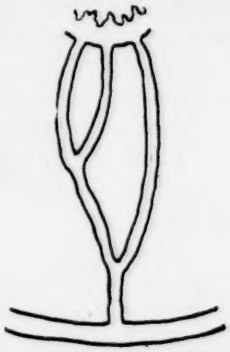

FIG. 6. Showing varying anastomoses.

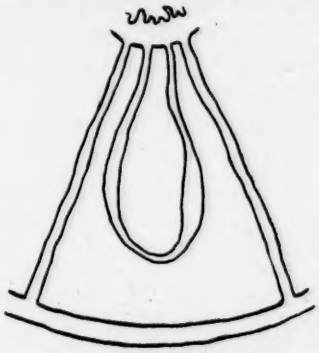

FIG. 7. Showing loop resulting from confluence of distal portions of adjacent canals.

my earlier paper (*op. cit.*) I have figured and described very similar features in *Gonionemus*, and Agassiz and Woodworth have likewise described similar features in the genus *Eucope*.[1] I incline to doubt whether any particular significance may be said to attach to such variations as these. It is certainly hard to discern any particular selective value they might have in the betterment of the species. It seems rather to be illustrative of those types of indefinite or fluctuating variations which abound more or less throughout the organic world, but having little or no bearing or significance in natural selection.

[1] "Variations in the Genus *Eucope*," *Bul. Mus. Comp. Zool.*, Vol. XXX.

3. *Spurs.* — These features are among the most common of the variant phenomena associated with the radial canals. Very few medusæ fail to exhibit something of the sort in greater or less degree. They are, however, more than usually abundant in *Rhegmatodes*. In a forthcoming paper on "Variations Among the Scyphomedusæ"[1] I call attention to similar conditions associated with the abundant anastomoses which occur in species of *Aurelia*. As shown in several of the accompanying figures, especially 9 to 12, they probably have some such relation in *Rhegmatodes*.

4. *Anastomoses.* — These are features, as just suggested, involving to some extent the preceding, and almost as common, especially in *Rhegmatodes*. Figs. 10 to 14 are a few illustrations of a condition found in many specimens, both small and large. Whether a similar condition may be found to occur in other Æquoridæ I do not know, or whether similar features exist in other of the Hydromedusæ having supernumerary canals is apparently unknown. When compared with the complex canal system found in the genus *Aurelia* it would at once suggest the query as to whether it might imply any phyletic relation with these medusæ. But this does not seem to me to be the case. It has probably only a more or less indefinite correspondence in the most general way, barely enough likeness to suggest a remote parallelism, but nothing of greater significance. Furthermore, as suggested in the previous section, it is difficult to perceive anything like a definite variation in a given direction, tending toward the establishment of a type of hydromedusa with a complicated and correlated canal system such as that of *Aurelia*. And while the total of these variational features reached as high as 27 per cent., which is but slightly higher

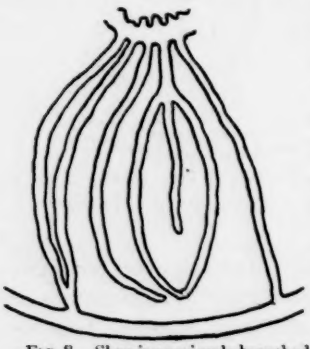

FIG. 8. Showing variously branched and united canals.

[1] "Variations Among the Scyphomedusæ," *Jour. Exp. Zool.*, Vol. II.

than the ratio I have found in *Aurelia* (*op. cit.*), it may still be doubted whether it sustains any direct selectional value to the species, any more than in the case of *Aurelia*.

GONADS.

The gonads are closely correlated with the radial canals, forming a double fold along the line of each canal. In not a few cases it was found that the gonads of certain canals were more or less rudimentary. Whether this may have been due to arrested development, or to some wholly unrecognized cause it is impossible to say. As a rule, it may be said that in those canals marked by incompleteness, as in Figs. 2, 3 and 4, the gonads were of this character, *i. e.*, showed signs of arrested development, or atrophy. An apparent exception was observed in the case shown in Fig. 7, where in the loops formed the gonads were

FIG. 9. Showing variations in branching, etc.

FIG. 10. Showing spurs.

larger and better developed than those of the normal canals of the same specimen. I think an explanation of this condition may be found in the fact that here the short loops of the canals were in closer connection with the gastric pouch, and thus provided with a larger food supply than in either of those of such incompleteness as shown in Figs. 2–4, or indeed the normal canals. Aside from these rather incidental aspects of variation there was little to call for special emphasis, or fuller details.

Tentacles.

As intimated in the outstart, there has been given but slight attention to variations in these organs. The tentacles of *Rhegmatodes* are both numerous and extremely delicate. It is therefore, difficult to distinguish numerical variations, or irregularity in position. I shall call attention only to one feature, concerning which, however, there is little to be said, the occurrence of branching, or bifurcation. This is a fairly common feature in many medusæ, and in my earlier paper I have figured and described numerous cases. Agassiz and Woodworth (*op. cit.*), have also described several cases among the Eucopidæ. Though somewhat careful attention was directed to this in *Rhegmatodes* anything of the sort is extremely rare. Only a single instance

Fig. 11. Showing union of basal canals in a single one.

Fig. 12. Showing anastomosis and imperfect canal.

of what seemed to be a basal bifurcation of a tentacle was detected, and that was not so evident as to be absolutely certain.

As a final word upon this feature it may be stated that as a rule the number of tentacles was usually greater as the specimens increase in size. To this, however, there were many exceptions. For example, one specimen measuring 47 mm. in diameter had 66 tentacles, while another which measured but 36 mm. in diameter had 69 tentacles. This may be taken as somewhat typical of many similar cases. In the paper of 1901, already cited, I have called attention to numerous instances of a

similar sort in *Gonionemus*. But as said in another connection, I do not attribute any particular significance to this feature in species like these, in which the numbers are large.

Otocysts.

The limited attention directed to these organs gave very much the same results as in the case of tentacles. Ordinarily they are said to occur in a more or less regular order between the bases

Fig. 13. Showing anastomoses.

Fig. 14. Showing loops and anastomoses.

of the tentacles; and in some species this order is very exact, for the most part. But in *Rhegmatodes*, as in *Gonionemus* (*op. cit.*), this does not seem to be the case. While difficult in preserved material to determine in many cases the presence or absence of these minute bodies with exactness, still a careful search in many of the most favorable specimens failed to detect anything like a definite and symmetrical distribution of them. Agassiz (*op. cit.*) has described a single one between the bases of contiguous tentacles. In many cases two were found, and in a few cases even more. But as intimated above, both the difficulty of their determination, and the great liability of loss of tentacles make the matter of a dogmatic statement on this point unwarranted.

Syracuse University,
September 9, 1905.

ON SOME FACTORS GOVERNING THE PERMEABILITY OF THE EGG MEMBRANE BY THE SPERM.

H. H. NEWMAN.

In the summer of 1903 Loeb[1] succeeded, by slightly increasing the alkalinity of sea water, in fertilizing the eggs of the sea-urchin (*Strongylocentrotus purpuratus*) with the sperm of the 20-rayed starfish, with that of Asterias and with that of the Holothurian, *Cucumaria*, while at the same time the eggs were rendered immune to their own sperm.

The question arose as to the character of the change in the egg or in the sperm that makes the former sometimes permeable to its own sperm and impermeable to foreign sperm and sometimes impermeable to its own sperm but quite freely permeable to the sperm of other species.

In one place Loeb tentatively suggests, "that the whole effect of the alkali is simply to bring about a slight physical change in the condition of the protoplasm of the egg, or the surface of the spermatozoön, which facilitates the entrance of the latter into the egg"; and in a continuation of the same series of experiments,[2] published some months later, he suggests "that the main variable determining the entrance of the spermatozoön into the egg may be of the nature of surface tension or a function of the latter."

In the following year Morgan[3] published a paper on "Self-Fertilization Induced by Artificial Means," in which he gives an account of some experiments performed on the eggs and sperm of several tunicates.

Under normal conditions the eggs of one individual cannot be fertilized by its own sperm, but, by treating the eggs and sperm with certain amounts of ether, he was able to get large percentages of self-fertilizations.

[1] Loeb, University of California Publications, Physiology, Vol. I., No. 6, pp. 39–53.

[2] Loeb, University of California Publications, Physiology, Vol. I., No. 11, pp. 83–85.

[3] Morgan, *Journal of Experimental Zoölogy*, Vol. I., No. 11, 1904.

Among the possible explanations of this phenomenon Morgan suggests "that the surface tension of the egg is of such a sort that it excludes the sperm of the same individual, but this idea does not appear to give a satisfactory solution, for, aside from the fact that it is difficult to imagine how such a relation could exist, there would also occur cases in which the surface tension of the eggs of other individuals would exclude certain sperm, and this would not appear to be the case. It is true that the addition of the ether to the water may cause a difference in the surface tension of the egg, and it might be made to appear that this was the way in which the self-fertilization is effected in ether solutions, but I cannot believe that this is the explanation, because other experiments show that a considerable amount of ether is necessary to cause self-fertilization."

In a later paper,[1] dealing with the same tunicates, Morgan corrects his previous observations to some extent and shows by a series of experiments that "it is not true that the sperm of a given individual will fertilize equally well the eggs of all other individuals."

As a matter of fact his tables show that the sperm of some individuals is wholly ineffective on the eggs of other individuals, and that all degrees of effectiveness are found. Thus his later experiments serve to offset his chief objection (quoted above) to the idea that surface tension might be an effective factor in controlling the entrance of the sperm into the egg.

Morgan showed that the addition of certain amounts of ether to sea water made the sperm more active, and he inferred from this fact that the activity of the sperm was the factor governing fertilization. On the other hand, he states that eggs have been fertilized by very inactive sperm. This seems to indicate that the activity of the sperm is a subordinate factor in fertilization. Moreover, no matter how slow-moving the sperm might be, some would undoubtedly be able to reach some eggs. The failure to fertilize would not then be due, I believe, to a failure of the sperm to reach the egg-membrane, but rather to a failure to fuse with and penetrate the latter. The fusion, as both Loeb and Morgan have suggested, may very readily be dependent upon surface tension.

[1] Morgan, BIOLOGICAL BULLETIN, Vol. VIII., No. 6, 1905.

At the suggestion of Dr. A. P. Mathews I took up this problem to see whether the surface tension, or the condition of the surface of the egg was of importance in determining fertilization. The working hypothesis was that the surface of the egg possessed a certain definite tension that rendered it permeable to sperm of equally definite surface tension. If the tension of either the egg or sperm is altered their fusion might no longer be possible, although the sperm of other species that might chance to possess a more appropriate surface tension might enter.

If the egg be a colloidal system with a membrane of a certain definite surface tension it should be possible so to alter this tension by the use of certain salts, that the sperm of the same species can no longer enter, and after so doing, to reverse the process and restore the original surface tension and the consequent permeability.

According to Mathews[1] the surface tension of colloidal particles or particles in suspension may be increased or decreased by means of salts acting through their tension coefficients. The egg may be regarded as a particle in suspension of which the membrane is electro-negative. It should be possible to increase its surface tension by neutralizing these charges either wholly or in part. A list of the tension coefficients of salts is given in Mathews' paper on the precipitation of colloids and at his suggestion I tried the alkaline earth chlorides, and particularly calcium chloride, as a salt which should increase surface tension, and sodium sulphate as a salt which should have an opposite effect on the surface of the egg.

The eggs of the minnow, *Fundulus heteroclitus*, were chosen for the experiment. These eggs are almost immune to changes in the osmotic pressure of the medium. It was noticed at the outset that eggs of *F. heteroclitus* became incapable of fertilization by their own sperm after exposure to sea water for periods in excess of an hour or in some cases an hour and a quarter. It seemed possible that the cause of this loss of susceptibility to fertilization might be due to certain salts in the sea water. This matter is partially cleared up by what follows.

The first experiments were undertaken to determine which

[1] Mathews, *Ameri an Journal of Physiology* XIV., 1905, p. 203.

salts were most powerful in shortening the period of susceptibility of the egg to its own sperm.

Experiment I. — Large numbers of eggs from various females were stripped into distilled water, mixed thoroughly and transferred to dishes containing respectively 100 c.c. of

A. $\frac{5}{10}$ *n.* $CaCl_2$, *C.* $\frac{6}{10}$ *n.* NaCl,
B. $\frac{5}{10}$ *n.* $MgCl_2$, *D.* $\frac{6}{10}$ *n.* KCl.

These solutions were made approximately isotonic with sea water so as to eliminate the factor of osmosis, although, as stated, these eggs are practically immune to osmotic changes. After periods of five, ten, twenty and thirty minutes' exposure to these solutions, successive lots of eggs — averaging about fifty in number — were taken out, washed in sea water and an attempt made to fertilize them in sea water.

The results of this experiment follow:

A. ($\frac{5}{10}$ *n.* $CaCl_2$). No eggs fertilized at all and all showed coagulation of the blastodisc or plasmolysis of the entire protoplasmic mass, after an exposure of five minutes or longer.

B. ($\frac{5}{10}$ *n.* $MgCl_2$). No eggs fertilized and all showed a vacuolated condition of the protoplasm and a considerable amount of plasmolyses after exposures of five minutes or longer.

C. ($\frac{6}{10}$ *n.* NaCl). About 30 per cent. of all eggs fertilized and cleaved normally and nearly all of these formed embryos, even after the maximum exposure of thirty minutes.

D. ($\frac{6}{10}$ *n.* KCl). From 60 to 75 per cent. of eggs fertilized and cleaved normally, producing normal embryos, even after the maximum exposure of thirty minutes.

From this experiment it will readily be seen that calcium salts are the most active in preventing fertilization, while sodium, and especially potassium salts, have relatively little inhibiting effect.

Experiment II. — In order to test the relative toxicity of these solutions before and after fertilization the following simple experiment was undertaken: A large number of eggs were fertilized in sea water, washed rapidly in distilled water and transferred to the same solution used in Experiment I. After standing in these solutions for thirty minutes they were returned to sea water

and allowed to develop. In every case nearly all eggs developed normally and formed embryos.[1]

It is worthy of note, then, that the egg becomes immensely more resistant to the toxic action of these salts after fertilization.

Several repetitions of Experiment I. showed an invariable order of activity from the most active to the least active —$CaCl_2$, $MgCl_2$, NaCl, KCl. It seemed advisable to include several other chlorides of these groups to see if their activity in inhibiting fertilization would fall in line with the theory of solution tension.

Experiment III. — A large number of eggs were stripped into distilled water, stirred and distributed into seven dishes containing :

A. $\frac{6}{10}$ *n.* LiCl,
B. $\frac{6}{10}$ *n.* NaCl,
C. $\frac{6}{10}$ *n.* KCl,
D. $\frac{5}{10}$ *n.* $MgCl_2$,
E. $\frac{5}{10}$ *n.* $CaCl_2$,
F. $\frac{5}{10}$ *n.* $SrCl_2$,
G. $\frac{5}{10}$ *n.* $BaCl_2$.

All eggs were allowed to remain in these solutions for five minutes, then washed and an attempt made to fertilize them in sea water, abundance of sperm being added in each case. It was found that so few of the eggs cleaved that a percentage basis could not be employed for all of the salts, yet it was quite evident that LiCl had an action between NaCl and $MgCl_2$, while $SrCl_2$ and $BaCl_2$ fell between $MgCl_2$ and $CaCl_2$.

Evidently the concentration of the seven salts used in this experiment was too great so it seemed advisable to determine the minimum concentration and the minimum time of exposure required by the most active of these salts — $CaCl_2$— for complete inhibition of fertilization. The following experiment enabled me to determine this.

Experiment IV.—Solutions of $\frac{1}{10}$ *n.*, $\frac{2}{10}$ *n.*, $\frac{3}{10}$ *n.* and $\frac{4}{10}$ *n.* solutions were made up and lots of eggs were exposed in each concentration for five, ten, twenty and thirty minutes before fertilization was tried. It was found that a $\frac{2}{10}$ *n.* $CaCl_2$ solution, after acting for five minutes allowed only 0 to 4 per cent. of eggs to become fertilized. This concentration and time of exposure should give a good percentage basis for estimating the activity of the seven salts used with reference to $CaCl_2$.

[1] See Mathews, *American Journal of Physiology*, X., 1904, p. 241.

Experiment V. — The same seven salts used in Experiment III. were used in $\frac{2}{10}$ *n.* solutions. The same method of procedure was used throughout as in Experiment III. and the results are given in the following table. The experiment was performed twice and the figures are given side by side for the sake of comparison.

	No. 1.				No. 2.		
	Salt.	No. of Eggs Used.	No. of Cleavages.	Per Cent. of Cleavages.	No. of Eggs Used.	No. of Cleavages.	Per Cent. of Cleavages.
A.	LiCl	72	41	57	38	25	68
B.	NaCl	80	64	80	34	26	76
C.	KCl	92	80	89	45	39	87
D.	$MgCl_2$	78	14	18	50	9	18
E.	$CaCl_2$	108	4	3.7	38	2	5.2
F.	$SrCl_2$	88	15	17	42	6	14.3
G.	$BaCl_2$	82	9	10.9	43	4	9.3

Averaging the percentages of cleavages in the two experiments we find that the salts arrange themselves as follows:—$CaCl_2$, 4.4; $BaCl_2$, 10.1; $SrCl_2$, 15.6; $MgCl_2$, 18; LiCl, 62.5; NaCl, 78; KCl, 88. This corresponds exactly with the order of the precipitating power of these salts on colloidal egg albumin and possibly with the order of the solution tensions of these cations.

These results seem to indicate that the cause of the inhibition of fertilization is of the nature of a precipitation of the colloids of the egg membrane. In order to demonstrate the possibility of rendering the egg impermeable to sperm of the same species and then reversing the coagulation so as to restore its permeability, a $\frac{2}{10}$ *n.* $CaCl_2$ solution was used as a precipitating or coagulating agent and a *m*/10 Na_2So_4 solution was used as a salt which theoretically should reverse the coagulation.

Experiment VI.—A lot of eggs were stripped into 100 c.c. of $\frac{2}{10}$ *n.* $CaCl_2$ solution and after a five minute exposure were divided into two dishes, one containing *m*/10 Na_2So_4 and the other containing sea water as a control. The control eggs were immediately mixed with an abundance of sperm, which was allowed to remain in the dish, but not a single egg cleaved. The eggs transferred to the *m*/10 Na_2So_4 solution were allowed to remain there for twenty minutes and were then transferred to sea water and fertilized. It was found in the course of about three hours that 27 out of 88 eggs had cleaved. The experiment was re-

peated and in this case the control showed two cleavages in 83 eggs while those treated with Na_2So_4 showed twenty normal embryos in 95 eggs.

Evidently, then, the antifertilization effect of the calcium ions on the egg may be reversed by sodium sulphate. Probably the $CaCl_2$ produces the gel condition in the egg membrane and the Na_2SO_4 redissolves the coagulum.

In order to test the hypotheses that the calcium or magnesium ions in sea water have the effect of slowly coagulating the membrane of the egg and of thus rendering it impermeable to its own sperm after a period of an hour or slightly more, the following experiment was undertaken:

Experiment VII. — A lot of eggs were stripped into distilled water, mixed thoroughly and then divided into five dishes containing respectively

A. Sea water.
B. $\frac{6}{10}$ *n.* KCl.
C. $\frac{6}{10}$ *n.* NaCl.
D. Equal parts of *B* and *C*.
E. $\frac{M}{10}$ Na_2SO_4.

After standing one and one-half hours a portion of the eggs from each dish was transferred to sea water, washed and an attempt made to fertilize, with the following result:

	Solution Used.	No. of Eggs Used.	No. of Embryos Formed.	Per Cent. of Embryos.
A.	Sea water.	78	0	0
B.	$\frac{6}{10}$ *n.* KCl.	45	14	31.1
C.	$\frac{6}{10}$ *n.* NaCl.	52	3	5.7
D.	Equal parts of *A* and *B*.	58	9	15.5
E.	M/10 Na_2SO_4.	63	42	66.6

After standing two and one-half hours another portion of the eggs was transferred from the original five dishes, washed and fertilized in sea water with the following result:

	Solution Used.	No. of Eggs Used.	No. of Embryos Formed.	Per Cent. of Embryos.
A.	Sea water.	68	0	0
B.	$\frac{6}{10}$ *n.* KCl.	51	8	15.7
C.	$\frac{6}{10}$ *n.* NaCl.	41	2	4.8
D.	Equal parts of *A* and *B*.	43	2	4.6
E.	M/10 Na_2SO_4.	58	14	24.1

After standing three and one-half hours the remainder of the eggs were transferred to sea water and fertilized, but in no case were any embryos formed.

The above series of experiments goes to show that the term of permeability of the egg membrane may be considerably prolonged by the exclusion of the calcium and magnesium salts. In no case, however, were the eggs capable of fertilization after standing for three and one half hours. It seems quite probable that the membrane is affected by internal changes in the protoplasm, which must be very active at this period. It is also to be noted that the $\frac{M}{10}Na_2SO_4$ solution helps the egg to retain its permeability longer than any of the ingredients of sea water. Further experimentation might lead to the discovery of a medium that would very greatly prolong the period of susceptibility to fertilization.

Conclusion. — These experiments show clearly enough that the membrane of the egg of *Fundulus heteroclitus* is subject to manipulation by the use of cations and anions, so that it becomes permeable or impermeable to its own sperm at the will of the investigator. I am unable to formulate any explanation of these changes in the condition of the membrane except that of a reversible coagulation and the consequent reversible surface tension.

When the surface tension of the egg is increased by coagulation of its colloids the sperm probably stands out on the surface of this altered membrane much as a minute droplet of water would stand out on the surface of an oil globule. Under ordinary conditions, however, the sperm surface and the egg surface are so adjusted to one another that they fuse on contact, and the sperm substance is engulfed by that of the egg.

We may suppose, then, that each species has a surface tension for the egg that is exactly suited to that of its own sperm and that, if altered, it becomes no longer suited to its own sperm but may become suited to other closely related sperm.

Loeb's results, cited at the beginning of this paper, offer evidence in favor of this view.

In the case of hermaphroditic animals, such as the tunicates with which Morgan worked, the condition is undoubtedly differ-

ent. It seems probable that the egg and sperm of the same individual have a slightly incompatible surface tension of egg and sperm, an incompatibility that may be removed by the action of ether. It may also be readily understood why the sperm of one individual is not equally effective on the eggs of all other individuals, for some eggs have a surface tension more suitable to that of the sperm than others.

If in any way one could overcome the difficulties of surface tension and could inject the sperm of unrelated forms beyond the egg membrane without injuring the egg, we might get some very significant results. This is a field as yet unexplored but I hope not unpromising. These experiments will probably be continued with other eggs and over a more extended field.

Summary.

1. The calcium salts are the most active of the salts found in sea water in inhibiting fertilization. They are also the most active salts in precipitating colloids. Hence there is probably a causal relation between the precipitation of colloids and the inhibition of fertilization.

2. The seven salts $CaCl_2$, $BaCl_2$, $SrCl_2$, $MgCl_2$, LiCl, NaCl, and KCl inhibit fertilization in the order of their tension coefficients. Thus the egg is acted upon as if it were a colloidal system.

3. Supposing the egg to be a colloidal system with a membrane negatively charged it should be possible to precipitate or coagulate this membrane by salts of high positive tension coefficients, such as $CaCl_2$, and to redissolve this precipitate or coagulum by the use of salts of high negative tension coefficients, such as Na_2So_4. This was done successfully, fertilization being inhibited by $CaCl_2$ and restored by Na_2SO_4.

4. This alteration in the character of the membrane must involve an alteration in the surface tension that controls the entrance of the sperm.

5. The short term of susceptibility of the egg to fertilization by its own sperm, when the eggs are allowed to stand in sea water is probably due to the presence of calcium salts that slowly coagulate the membrane and thus increase its surface tension. The period of susceptibility to fertilization is considerably pro-

longed in the absence of calcium salts and especially in a medium of Na_2So_4.

6. These experiments and those of Loeb and Morgan seem to indicate that the relative surface tension of the egg and of the sperm is one important factor governing fertilization.

MARINE BIOLOGICAL LABORATORY,
WOOD'S HOLL, MASS., August, 1905.

ON THE FOSSIL GENUS POROCYSTIS, CRAGIN.[1]

MAY M. JARVIS.

Under the name of *Porocystis pruniformis* F. W. Cragin described in 1892, in the Fourth Annual Report of the Geological Survey of Texas, curious spherical forms from the Cretaceous of Texas. In regard to the geological levels at which they were collected, he states: "In chalky limestones of the alternating beds in Travis, Burnet, Williamson, Lampasas and other counties, associated with Serpula, small Ostreidæ, and other forms indicative of moderate depth of water. In the Third Annual Report of the Survey, Mr. Taff has also recorded it from rocks of the Fredericksburg division of the Hickory-Cow Creek divide, Travis County, associated with several fossils of the *Exogyra Texana* beds."

Cragin considered that these fossils were Bryozoa, and speaks of having sent some to the late Dr. Ferdinand Roemer, who returned them marked "*? Parkeria*, sp. nov." His figures of them are not detailed, and for this reason as also because they are evidently not Bryozoa, a new description seems called for. There is a large series of specimens in the University Museum, the greater number considerably eroded but some with the surface sculpturation well preserved.

The tests are more or less prolate spheroids, sometimes one axis much shorter than the other. At one point on the surface is a flattened, very slightly protuberant area, free of any sculpturation, which might represent either the point of attachment of a stalk, or have been a large foramen. For various considerations it is probably the latter, so that the whole fossil proper would be a hollow spheroid with very thin shell and with a large opening at one end. The interior of each fossil is a mass of structureless limestone. This flattened area, or foramen as it may preferably be called, is usually upon the edge or very near it, when the specimen is much flattened, but in one of such cases it is in the center of the flat side. Canals radiate from the fora-

[1] Contributions from the Zoölogical Laboratory of the University of Texas, no. 70.

men, and the whole surface is covered with ridges and depressions.

The usual surface sculpturation consists of rather irregular rows of approximately oval or circular depressions the centers of

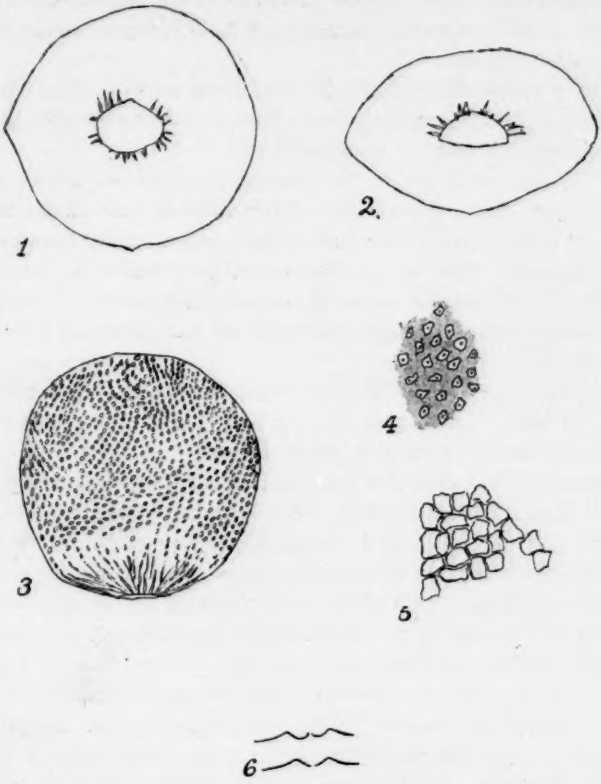

FIG. 1. Medium-sized specimen, showing general form, foramen and radiating canals.

FIG. 2. Specimen with one short axis, diameter 12 by 19 mm.

FIG. 3. Medium-sized specimen, diameter 18 by 18 mm.

FIGS. 4, 5. Different types of surface sculpturation.

FIG. 6. Ideal cross-section of test alone.

which are in some specimens raised into papillæ (Fig. 4). Some have flat scar-like white areas with traces of the more prevalent sculpturation (Fig. 5). Others have raised areas of the same

shape and arrangement ; these seem to indicate an erosion of the ridges and the papillæ. In some, again, the ridges have worn away, leaving only the papillæ, but the arrangement of these is as in the other cases. At the summit of each papilla, or at the center of each depressed area, is a minute foramen penetrating the wall of the test.

Fig. 7 shows the structure in ideal cross section. The whole interior is filled completely with foreign, calcareous substance, containing fragments of sponge spicules.

In no one specimen is the sculpturation preserved over the entire fossil, but a comparison of the different ones shows that the test in life, except just around the foramen, must have been so sculptured. The radial canals around the foramen are usually continued upwards as rows of minute depressions. Possibly such radial canals were not present in life, but produced by erosion of the exterior.

Measurements. — The largest specimens have a diameter of 25 × 31 mm. ; smaller ones from 9 to 18 mm. The large basal foramen measures from 4 to 7 mm. across.

These fossils present few good characteristics to enable one to decide what their nature was. But there is no resemblance, as Cragin had supposed, to Bryozoa, for even in a colonial ectoproctous Bryozoan the cysts of the separate individuals are more or less cylindrical, and there is no sign at all of any such structures. Evidently the structure is that of a very thin shell or test, without prolongations into the interior, with a large opening at one end and rows of numerous minute foramina elsewhere upon the surface. This general appearance suggests that it is a gigantic monothalamnian Foraminifer that in the course of fossilization has become infiltrated so as to be quite solid. Were it Bryozoan there should be present traces of skeletal parts within the test.

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